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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

The Giant Moth Borer:

The most dreaded of all sugar cane insect pests entered Hawaii alive in April of the present year and was discovered and destroyed three months later. A description of the insect and the circumstances involved in its introduction are given together with a discussion of the damage caused by it to sugar cane in other countries.

Emergency Conservation Work in Hawaii:

The nature and extent of the Conservation work being carried on quietly but effectively throughout the Territory is well illustrated by the two quarterly reports of L. W. Bryan, which we are printing in this number of the Record with the consent of James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii.

Studies of Enzyme Action in Sugar Cane:

This is a non-technical account of some of the more important characteristics of enzymes, those active agents which enable plants and animals to carry on the chemical changes essential to life at the temperature of the living plant or animal. The paper is offered as an introduction to the enzyme studies now being conducted at the Experiment Station.

Plant Food Values in Molasses and Filter Cake:

A progress report is made on the results that have been secured from a series of pot tests, wherein an attempt is being made to evaluate the plant food that is carried by molasses and filter cake. The results give rather definite indications that the potash and phosphate contained in these two by-product materials have a crop-producing power that is fully equal to or better than equivalent amounts of the nutrients from commercial fertilizer.

The evaluation of their nitrogen content is somewhat complicated. There is undoubtedly some loss of nitrogen to the growing crop from the total available

supply, when these highly carbonaceous materials are used. No attempt is made to explain this loss, although it may probably be associated with the differences between the nitrogen-carbon ratios of the soils and of the two by-products that were applied thereto.

Two Sugar Cane Pests in Guatemala:

An interesting account is given of two sugar cane pests which F. A. Bianchi studied while in Guatemala. These pests, the one a large stem-boring beetle, the other a root-feeding bug, were found capable of doing serious damage to sugar cane.

Sources of Nitrogen:

The probable influence which the soil reaction has upon the comparative efficiencies of several sources of nitrogen was quite definitely shown when these several materials were applied in solution in water to various soils which were potted and planted with Sudan grass. Anhydrous ammonia was less effective than ammonium sulphate on the neutral and slightly alkaline soils but this efficiency decreased where the slightly acid and acid soil type were concerned.

Giant Sugar Cane Moth Borer Intercepted in Honolulu

By C. E. PEMBERTON

On April 12, 1935, a Honolulu resident imported from the Panama Canal Zone 12 corms of the ornamental plants *Heliconia angustifolia* and *Heliconia bihai*, there being six plants of each species. This introduction was in compliance with the Territorial Plant Quarantine regulations, an application for the importation having been duly filed and granted. The material was fumigated by a plant quarantine officer and, in the ordinary course of events, would have been immediately released to the importer. Fortunately, however, Dr. H. L. Lyon was consulted by the Chief Plant Inspector respecting the advisability of releasing this material after fumigation. Dr. Lyon was of the opinion that its immediate release would be unsafe in spite of the fumigation, because of the fleshy nature of the corms and the uncertainty of penetration by the fumigation gases into the interior, where borers or other insects might be concealed. The importer agreed to permit the retention of the plants in a tightly screened quarantine house in Dr. Lyon's care in order that they might be kept under observation for some time. This was done.

On July 16, 1935, Dr. Lyon observed a large handsomely colored moth flying about in the quarantine house. This was captured, killed and later identified by O. H. Swezey as a form of *Castnia licus* Drury, the dreaded Giant Sugar Cane Moth Borer of tropical America. Close examination of the plant material showed where the large larva matured in the root stalk of one of the *Heliconia angustifolia* plants and formed a pupa from which the moth had finally emerged.

We have here a case in which the worst known pest of sugar cane reached our shores alive and in perfect condition, after having passed through the regular procedure of fumigation administered to all imported plants from most outside localities by our Plant Quarantine Service. This pest was only prevented from escaping into the open through a fortunate combination of circumstances. Present quarantine methods of fumigation and release of plant material to the importing public are clearly shown to be inadequate for our protection. If fumigation will not render imported plant material safe, such material should not be permitted entry into the Territory until facilities for its safe treatment and handling are provided.

Should the Giant Sugar Cane Moth Borer become established in Hawaii, millions of dollars to the sugar industry would be annually lost. No effective parasites are known on it. Certain birds in Trinidad and Guiana are the most useful enemies on record and are encouraged to live in the cane fields of those countries through the provision of bamboo bird perches throughout the cane fields. This moth borer is so bad in some regions that rats, which eat out the larvae from the stalks, are said to be protected on one estate. An active drive was even made against the mongoose in order that the rats would have better opportunity to increase in the cane fields. Flooding the fields for 72 hours has been said to be an effective remedy in British Guiana, where the cane is all on flat, low land surrounded by water. There are few spots in Hawaii, if any, where this could be done. The only other method of control

so far known is the capture of the adult moths with butterfly nets and the digging out of the large larvae from the stools after harvest, which is slow and very expensive.

The larva of the giant moth borer, when mature, may measure four inches in length and one-half inch in diameter. The moth spreads from three to four inches across the wings. A single larva becomes so large and powerful when full grown that the cane it occupies may be completely ruined, from the milling standpoint. Shortly before pupating the larva bores down through the stalk into the underground portion of the stool, where it pupates. In consequence of this, few of the well-grown larvae are killed in the process of harvesting, since they are not carried to the mill in the cane but are left behind in the stool to hatch into moths and carry on the destruction.

Like many pests of the sugar cane plant, the giant moth borer infests other plants besides cane, which include at least the two species of *Heliconia* above mentioned, bananas and plantains, young coconut palms, another palm *Oreodoxa oleracea* in Trinidad, and rarely in at least one species of grass on the same island, according to Myers (1). The danger of importing new pests of sugar cane in other plants is well demonstrated in the case under discussion.

The following extracts taken from the published reports of three entomologists who have studied the giant moth borer, will give a fair picture of the importance of this pest in the cane countries where it occurs.

Myers (1) states that in Trinidad:

... it is now widespread and increasing in destructive activity. It is possible to find carts of "farmer's" canes 90 per cent. of which have been bored by this insect. And one boring by such a large larva is more destructive than many by *Diatraea*. In Trinidad cane-fields, save an infinitesimal minority near the Caroni River, flooding is quite impracticable, and the only method of direct control is hand-collecting of the larvae from young canes and from cut stools, coupled with the capture of the adult moths.

In this way, on one estate (Skinner, 1929), 356,000 moths were destroyed between July 1927 and January 1928. This was followed by a campaign against the larvae, of which 1,667,357 were paid for between January and November, 1928. . . .

There is a significant difference between the giant-borer and the small borers (*Diatraea*), for whereas the latter, when the canes are cut, are carried, in the vast majority, into the mill and destroyed when the canes are crushed, the former are left in the stool, where they may easily continue their development and emerge as moths.

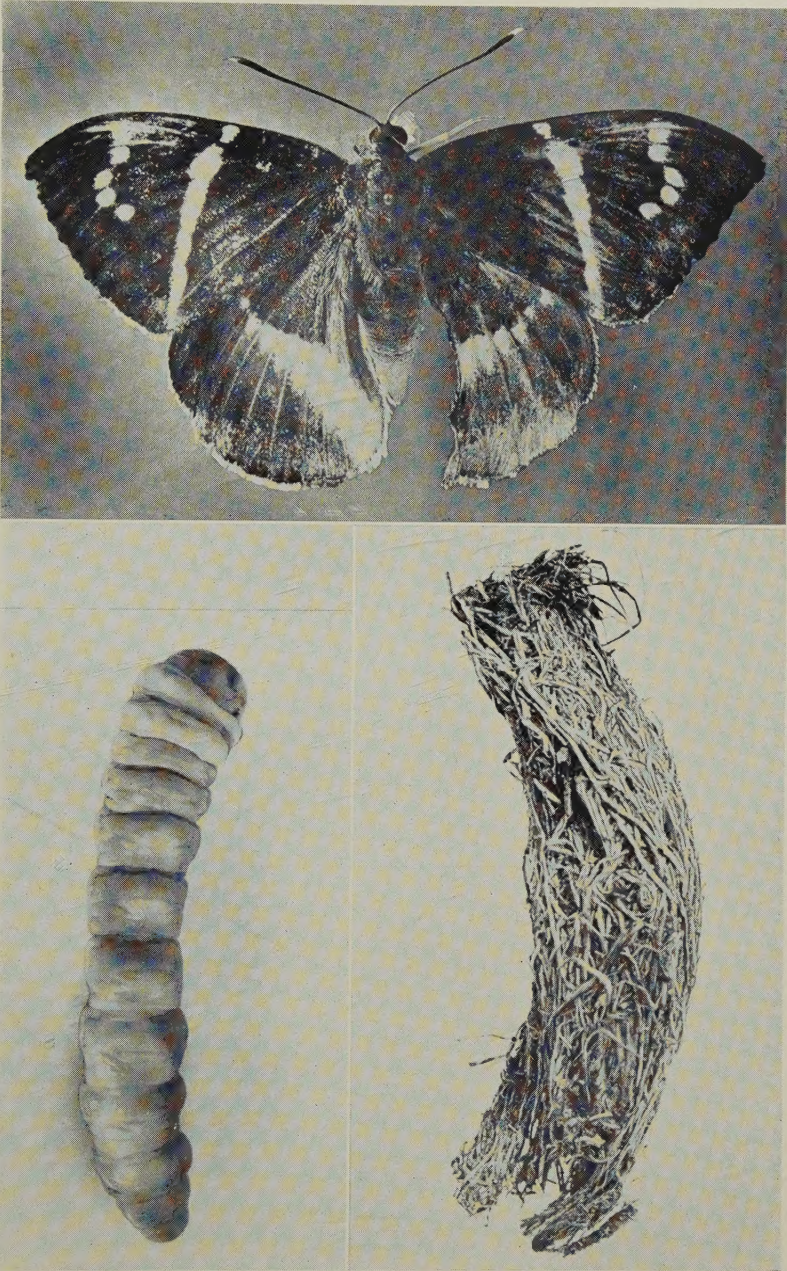
Skinner (2) remarks that:

Unlike the small moth borers, *Diatraea* spp., which cause enormous losses [in many countries] *Castnia licus* is confined to Trinidad, British Guiana and some other parts of South America where its depredations may be very severe. A severe outbreak of this borer in Demerara was investigated by Queleh (4) and his conclusions were published in 1910. In the same year, Urich (5) called attention to *Castnia licus* as a possible future pest of sugar cane, but it is only during the past two or three years that it has increased in the southern part of Trinidad to major pest proportions.

In 1927-28, this pest increased to an alarming extent in the Naparima district of Trinidad and the losses resulting exceeded those due to *Diatraea* and to the Frog-hopper. . . .

Fully grown larvae (and also adult moths) vary considerably in size; when fed on large succulent cane, they may measure as much as four inches in length and $\frac{1}{2}$ inch in diameter in front, but specimens of half this size are encountered. They are voracious feeders, tearing the cane fibres with their powerful mandibles, expressing the juice which they swallow and rejecting the fibre which they work down behind them, large quantities . . . being always found in their burrows. . . .

In badly infested areas, the damage caused by *Castnia licus* is enormous. Parts of fields have been seen in which practically every stool has been attacked and with 50 per cent. or more of the cane bored. A single *Castnia* larva can destroy as much as $1\frac{1}{2}$ to 2 feet of canes apart



Giant sugar cane moth borer showing adult moth, larva and cocoon, all natural size.

from boring down in the root stock. In addition to the loss of weight due to boring, the unbored portion sometimes dries up and is lost or at best deteriorates very considerably in purity and

sucrose content, whilst the glucose ratio is greatly increased. The boring of the root stock weakens the stool greatly, completely destroying it in some cases, and invariably reducing its ratooning powers. Enormous numbers of young shoots and suckers are converted into "dead-hearts," which means that they never produce cane. It is probably not an exaggeration to say that, in badly attacked fields, the loss may easily reach 25 per cent. of the crop.

Wolcott (3), in his book on the economic entomology of the West Indies, writes as follows regarding *Castnia* damage to sugar cane:

It may well be imagined how serious is the injury that even one caterpillar can cause. When the cane is young, one individual will often kill several stalks, so that one can readily notice the injury looking over a cane-field. Older cane is not killed by *Castnia* caterpillars, for the larva eats only the sweet pithy inside of the cane, so that growth at the top is not appreciably checked. It is only when the cane is cut that one can accurately determine the extent of the injury, as then the large holes in the stubble are most noticeable; or looking at the cane in the cane ears, the number of hollow bases gives an index of infestation.

The intercepted moth and cocoon from which it hatched are shown in the accompanying illustration together with a larva collected by Dr. F. X. Williams in South America several years ago. The photographs, by Wm. Twigg-Smith, show the specimens in natural size.

LITERATURE CITED

- (1) Myers, J. G., 1931. A preliminary report on an investigation into the biological control of West Indian insect pests. Publication of the Empire Marketing Board, No. 42, pp. 102-105.
 - (2) Skinner, H. Martyn, 1930. The giant moth borer of sugar-cane. Supplement to Tropical Agriculture, January 1930, 8 pages, 1 plate, 2 figures.
 - (3) Wolcott, George N., 1933. An economic entomology of the West Indies. The Entomological Society of Puerto Rico, San Juan, p. 144.
 - (4) Quelch, John J., 1910. Report on the giant moth borer. Georgetown, Demerara. The Argosy Co., Ltd.
 - (5) Ulrich, F. W., 1910. The cane sucker (*Castnia licus*). Bulletin of the Department of Agriculture, Trinidad, Vol. IX, p. 43.
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Emergency Conservation Work Associate Forester's Narrative Report Island of Hawaii For October, November and December, 1934*

GENERAL

Our second enrollment period began on October 1, with 59 enrolled men, 7 foremen and 1 clerk. All of these enrolled men continue to live at home, furnish their own subsistence, and are paid at the rate of \$2.00 per day, five days per week. Actually, some of these men spend part of their time in temporary camps in order to be close to their work. These camps are furnished them gratis and such equipment as has been needed has been purchased with ECW funds. The men purchase their own food supplies and do their own cooking. This system has worked out to advantage on some of our projects that are too far away to be economically handled from the enrollees' homes.

The average age of our enrolled men is 26 years and they are divided into racial groups as follows:

Japanese	19
Portuguese	18
Caucasian-Hawaiian	9
Hawaiian	5
Caucasian-Chinese	2
Chinese	2
Korean	1
Hawaiian-Chinese	1
Korean-Hawaiian	1
Caucasian	1
Total.....	59

During the first quarter of our second enrollment period we have lost 9 enrolled men through discharge and have had 3 accidents requiring medical attention. Eighty-four per cent of our first enrollment period men were re-enrolled to serve an additional six months period.

Technical supervision and local administration of the work have been continued under the direction of local officials of the Territorial Division of Forestry.

EQUIPMENT

All of our ECW equipment has been maintained in good condition, particular care being taken with trucks and other cars. No new heavy equipment has been

* We are indebted to James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii, for the privilege of printing this report by L. W. Bryan.

needed since the beginning of ECW. New minor equipment has been secured as needed.

WORK ACCOMPLISHED

Our program of work for this island is divided into the following:

- (a) Nursery Work
- (b) Planting, Maintenance
- (c) Planting, Forestation
- (d) Truck Trail Construction
- (e) Horse Trail Construction
- (f) Fence Building
- (g) Firebreak
- (h) Elimination of Useless Range Stock
- (i) Structures

(a) *Nursery Work:*

In addition to supplying trees needed for our ECW program requirements, we have been able to maintain a surplus which has been distributed to homesteaders, farmers and others for general planting. On Arbor Day, November 9, a total of 11,467 trees, shrubs and vines were given away from the Hilo Nursery in accordance with our usual custom. A total of 100,414 trees have been distributed during the period covered by this report.

(b) *Planting, Maintenance:*

In Hawaii, with our heavy rainfall and twelve months growing season, considerable follow-up work is necessary in order to insure our young trees against being choked out by rapid-growing grass and other weeds. All young trees planted must be gone over and cleaned around at least once, frequently twice, and sometimes three cleanings are found necessary, depending upon the species of tree used and the type of weeds found growing in a given locality.

During the past three months we have cleaned around 174 acres of trees which were planted out during our first enrollment period. In laying plans for this work, at the beginning of this period, we estimated that there would be a ten per cent mortality in trees planted. Actually our mortality has fallen below this figure for out of the 174 acres cleaned we have been obliged to replant only 15.63 acres or nine per cent.

(c) *Planting, Forestation:*

Our program calls for the planting of trees on 200 acres of land located within four different forest reserves in ten different localities.

The following tabulation shows what has been accomplished to date:

Hilo Forest Reserve

Land of Piihonua:

Eucalyptus microcorys	788
Eucalyptus robusta	15,566
Eucalyptus saligna	459

16,813 trees 38.65 acres

Land of Laupahoe:

Eucalyptus resinifera	1,970
Thuja occidentalis	44

2,014 trees 4.63 acres

Total, Hilo Reserve..... 18,827 trees 43.28 acres
Kohala Forest Reserve

Land of Puukapu:

Eucalyptus resinifera	1,281
Eucalyptus rostrata	2,581

3,862 trees 8.88 acres

Land of Lanikepu:

Eucalyptus robusta	1,341 trees	3.08 acres
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Total, Kohala Reserve..... 5,203 trees 11.96 acres
Waiaha Spring Forest Reserve

Land of Waiaha:

Eucalyptus robusta	2,358 trees	5.43 acres
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Total, Waiaha Spring Reserve.. 2,358 trees 5.43 acres
Hamakua Forest Reserve

Land of Honokaia:

Eucalyptus paniculata	332
Eucalyptus robusta	1,008
Eucalyptus rostrata	46
Eucalyptus siderophloia	86

1,472 trees 3.38 acres

Land of Hoca-Kaao:

Casuarina glauca	53
Eucalyptus saligna	300

353 trees .81 acre

Land of Kaohe:

Eucalyptus microcorys	1,608	
Eucalyptus paniculata	2,840	
Eucalyptus resinifera	554	
Eucalyptus rostrata	5,018	
	10,020 trees	23.03 acres
Total, Hamakua Reserve.....	11,845 trees	27.22 acres
Total, Island of Hawaii.....	38,233 trees	87.89 acres

(d) *Truck Trail Construction:*

Our program provides for construction of two truck trails, one of 6.00 miles in length along part of the upper boundary of the Hilo Reserve and one, 2.50 miles long, within the Nanawale Reserve. Work on these trails has gone along satisfactorily and the following has been completed:

Keanakolu-Hopowai Truck Trail.....	2.88 miles
Nanawale Truck Trail.....	.25 "
Total.....	3.13 miles

In addition to these two truck trails it was found necessary to construct a truck trail in order to reach the land of Kaohe within the Hamakua Reserve. This was necessary in order to eliminate mule packing of trees and fence materials in this section. The total length of this truck trail is 1.75 miles and with it in use we have been able to truck in all of our trees, fence materials and labor. This makes a total of 4.88 miles of truck trails completed.

(e) *Horse Trail Construction:*

In the Kohala Reserve, Land of Pololu, our program calls for the rebuilding of 1.20 miles of horse trail. To date we have completed 0.78 mile of this trail or over one-half of this project. This trail follows easy grades, is six feet wide, and when finished will connect the lower government trail with the upper ditch trail.

(f) *Fence Building:*

Our original program provided for the construction of two new fences, one in the land of Puukapu, Kohala Reserve, and one in the land of Kaohe, Hamakua Reserve, a total length of 2.05 miles. In addition to this it was found necessary to build an additional 1.08 miles of fence in order to provide enclosed areas around our new shelter houses on Mauna Kea for work animals being used by our men engaged in Elimination of Useless Range Stock in this section.

The following table shows what has been done to date:

Puukapu Fence	0.84 mile
Kaohe Fence	0.64 "
Mauna Kea Fences	1.08 miles
Total.....	2.56 miles

The Puukapu fence is being constructed throughout with No. 1047 galvanized stock wire and redwood posts. The Kaohe fence is being made partly with this same material and partly with ohia posts and 5 strands of No. 6 smooth, galvanized wire. The Mauna Kea fences are constructed of No. 1155 stock wire and the posts were cut from local mamani trees. Suitable gates have been installed where needed.

(g) *Firebreak:*

This project, as planned, called for the clearing out of an old Hawaiian trail leading from the National Guard Rifle Range to the Keaau Boundary across part of the land of Waiakea. After the work was started we found that it would save time to be able to drive our trucks in on this firebreak. This required a little extra work but it has been well worth the effort as we can now take our trucks with labor and tools right in as far as the work has progressed. This will be of great advantage in case of fire in this section. To date we have completed 2.58 of the proposed 4.50 miles.

(h) *Elimination of Useless Range Stock:*

This problem is a serious one and one that will require much time and effort to bring to a successful termination. Much preliminary work is necessary before we can safely venture to attempt the poisoning of these animals on a large scale. At present we are experimenting to find a suitable bait to which we can later add poison.

On this Island there are many thousands of wild goats, sheep and pigs and they constitute a serious menace to sections of our forests. Within the Mauna Kea Forest Reserve (an area of 68,272 acres) the wild sheep and goats are so numerous that it is impossible to find any natural reproduction of the predominating tree growth, mamani (*Sophora chrysophylla*). These animals are very fond of this tree and if they are not eliminated, or greatly reduced in numbers, it will be only a matter of time before this section will be completely denuded.

To date we have confined our activities to the shooting of these pests. At the beginning of the program this work was delayed by the Finance Officer's refusal to pay for arms and ammunition. This matter was finally settled and sufficient ammunition and arms have been ordered to carry on this part of the work. During the past three months 1,139 of these animals have been killed.

(i) *Structures:*

Our approved program did not specify any particular number of structures but in order to provide places for our men to stay while engaged in the Elimination of Useless Range Stock on Mauna Kea, it was found necessary to construct three small shelter houses at different points on the mountain. These buildings are all alike; 12 x 16 feet, constructed of T&G, with galvanized iron roof, 2,000-gallon water tank, built-in bunks, iron sink, small stove and necessary cooking and eating utensils to accommodate six men. They are located on the mountain at about 8,000 feet elevation and are working out very well in practice, and will always be of value in our regular routine forest work. Around each shelter we have fenced off an area in which to pasture such work animals as are necessary to carry on this work.

PHOTOGRAPHS

A number of photographs are included showing some of the work being done.

L. W. BRYAN, Associate Forester.



Plant benches with young forest trees at the Hilo Nursery.



Puu Kahinahina shelter for use of men engaged in elimination of wild sheep, Mauna Kea Reserve.



Widening out old Hawaiian trail, Nanawale truck trail.



Working on Nanawale truck trail.



Pulling guava stumps, Waiakea firebreak.



Preparing holes for tree planting, land of Puukapu, Kohala Reserve.

Emergency Conservation Work Associate Forester's Narrative Report Island of Hawaii For January, February and March, 1935*

GENERAL

This report covers the last quarter of our first year's work under ECW on Hawaii. During this quarter we have completed practically all of our contemplated projects and in addition have accomplished more along certain lines than was at first expected. All of our men continue to live at home, work 5 days per week and are paid at the rate of \$2.00 per day for juniors, and \$2.50 per day for experienced men. At the close of the quarter we had the following:

- 110 Junior Enrolled Men
- 8 Experienced Enrolled Men
- 8 Foremen
- 1 Clerk

and in addition, three foremen and one project superintendent were employed during the latter part of the quarter to assist in getting ready for our new program which has been approved for this Island.

During this quarter we have expended a total of 9,343 man-days on all of our projects; we have lost 8 enrolled men through discharge; have had 5 accidents requiring medical attention and have lost 13 man-days due to these accidents.

All technical supervision and local administration have been cared for by local officials of the Territorial Division of Forestry.

Considerable work has been done on our new set-up for the fifth enrollment period. Plans for our camps have been prepared and actual work on their construction has been started. Wire for our fence as well as other equipment has been ordered. Due to failure of early passage of the relief bill we were not able to start construction of our water tanks at the new Keanakolu Camp. This delay may hold up the work in this section for several months for we must first secure rain water in our tanks before this camp can be utilized. Unfortunately the winter rains came while this important work was suspended.

EQUIPMENT

All of our equipment has been maintained in good condition. Our trucks and station wagons have been run for a total of 76,274 miles since we first secured them about one year ago. They are still in first class shape and good for many more miles.

* We are indebted to James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii, for the privilege of printing this report by L. W. Bryan.

WORK ACCOMPLISHED

Our program of work for this Island is divided into the following sections:

- (a) Firebreak
- (b) Truck Trail
- (c) Horse Trail
- (d) Other Structures
- (e) Fence, other than range
- (f) Planting, Forestation
- (g) Planting, Maintenance
- (h) Nursery
- (i) Elimination of Useless Range Stock.

(a) *Firebreak:*

The original estimated distance of this project was 4.50 miles. Actually we found, upon completion, that it was only 3.70 miles. During the first quarter we completed 2.58 miles and the remainder of 1.12 was completed during the period under consideration. This Firebreak, as constructed, enables us to traverse its entire length with our trucks, being a decided advantage in case of fire.

(b) *Truck Trails:*

Our original program called for the construction of 8.50 miles of truck trails during the fourth enrollment period. On February 7, a supplemental program was approved for 19.50 miles of truck trails on Mauna Kea making a total of 28.00 miles. The following tabulation shows what has been accomplished:

Keanakolu-Hopowai Truck Trail.....	7.00 miles
Nanawale Truck Trail.....	2.90 "
Kaohe Truck Trail.....	1.75 "
Umikoa-Keanakolu Truck Trail.....	9.00 "
Hanaipoe-Puu Mali Truck Trail.....	2.90 "
Kalaieha-Puu Hookomo Truck Trail.....	1.65 "
Laumaia-Puu Kahinahina Truck Trail.....	3.02 "
Total.....	28.22 miles

With the exception of the Nanawale Truck Trail all of the above were comparatively easy to construct. The Nanawale Truck Trail was much more difficult and required much more time than was first contemplated.

(c) *Horse Trail:*

Our approved program provided for the construction of 1.20 miles of horse trail in the land of Pololu, Kohala Forest Reserve. This work went along much faster than was expected and as a result we were able to extend this trail and complete it for a total distance of 2.32 miles.

(d) *Other Structures:*

These structures, three in number, were constructed as a part of our Elimination of Useless Range Stock Program and were completed during the first part of the enrollment period and reported in our last Narrative Report. They have worked out very well in practice making comfortable shelters for our men who are engaged in this work at high elevations on Mauna Kea.

(e) *Fence, other than range:*

A total of 3.24 miles of new fence has been constructed during this enrollment period as follows:

Puukapu Fence	1.14 miles
Kaohe Fence	.91 "
Mauna Kea Fences.....	1.19 "
Total.....	3.24 miles

(f) *Planting, Forestation:*

Our program calls for the planting out of 87,775 trees on 202 acres of land in ten different locations on four different forest reserves. Trees are planted about 10 x 10 feet or 435 trees to the acre. On some of the reserves we have planted less than we expected while on others we have planted more than our program calls for.

During the entire period there have been planted 89,187 trees on 205 acres of land as follows:

Hilo Forest Reserve

Land of Kaiwiki 3rd:

Eucalyptus robusta	393 trees	.90 acre
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Land of Laupahoehoe:

Eucalyptus resinifera	1,970	
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Thuja occidentalis	44	
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	2,014 trees	4.63 acres
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Land of Piihonua:

Eucalyptus microcorys	788	
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Eucalyptus robusta	15,566	
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Eucalyptus saligna	459	
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	16,813 trees	38.65 acres
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Total, Hilo Reserve.....	19,220 trees	44.18 acres

Kohala Forest Reserve

Land of Puukapu:

Casuarina glauca	10,035
Eucalyptus resinifera	1,281
Eucalyptus robusta	19,896
Eucalyptus rostrata	2,581

 33,793 trees 77.69 acres

Land of Lanikepu:

Eucalyptus robusta	1,341 trees	3.08 acres
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 Total, Kohala Reserve..... 35,134 trees 80.77 acres
Hamakua Forest Reserve

Land of Honokaia:

Casuarina glauca	2,540
Eucalyptus paniculata	725
Eucalyptus robusta	1,047
Eucalyptus rostrata	46
Eucalyptus siderophloia	86

 4,444 trees 10.22 acres

Land of Kaohe:

Eucalyptus microcorys	1,608
Eucalyptus paniculata	2,840
Eucalyptus resinifera	2,288
Eucalyptus rostrata	10,008
Grevillea robusta	5,407

 22,151 trees 50.91 acres

Land of Hoesa-Kaao:

Casuarina glauca	1,956
Eucalyptus saligna	300

 2,256 trees 5.18 acres

 Total, Hamakua Reserve..... 28,851 trees 66.31 acres
Waiaha Spring Forest Reserve

Land of Waiaha:

Eucalyptus robusta	5,982 trees	13.76 acres
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 Total, Waiaha Spring Reserve.. 5,982 trees 13.76 acres

 Total, Island of Hawaii..... 89,187 trees 205.02 acres

(g) *Planting, Maintenance:*

This is one of the most important phases of our work, for it is only by following up our plantings and keeping them free from weeds and grass, that we can be assured of a good stand of trees later.

During the past six months we have cleared around 165,735 trees on 381 acres of land. We originally estimated that there would be about ten per cent mortality. Actually we were obliged to re-plant only 32 acres or 8 per cent.

(h) *Nursery:*

The original project called for 786 man-days to be spent on nursery work. On February 7, an additional 500 man-days was approved as a supplemental project making a total of 1,286 man-days for this work. This additional labor was required in order to start the work of preparing additional planting material to be used during the fifth enrollment period. As a result of this additional 500 man-days we have been able to start a great many more trees which will be available for our planting during the first part of the next enrollment period.

During the six months period we have produced and distributed a total of 168,208 trees from the Hilo Nursery. We have also taken care of the surrounding grounds; gathered what seed we could locally; rebuilt 89 of the plant benches, using old iron rails with concrete foundations; constructed 10 new plant benches; constructed over 3,000 new plant flats; as well as other routine work.

(i) *Elimination of Useless Range Stock:*

Our activities along these lines have been extended to three different reserves and to shooting and driving wild goats, hogs and sheep. To date no practical method of poisoning these animals has been found fully successful. During the fifth enrollment period we plan to do extensive fence work on Mauna Kea which will greatly assist in controlling the thousands of wild sheep which are so abundant in this reserve. These animals are so plentiful that for a number of years there has been no natural reproduction of the predominating tree growth (*Sophora chrysophylla*) in this region, except in a few small sections that have been fenced so as to exclude all stock. By eliminating these pests we can expect a new forest growth to come back naturally.

During this enrollment period we have killed a total of 4,336 animals as shown in the following tabulation:

	Sheep	Pigs	Goats	Total
Mauna Kea Reserve.....	2554	88	7	2649
South Kona Reserve.....		3	1515	1518
Honuaula Reserve	15	9	145	169
Totals.....	2569	100	1667	4336

PHOTOGRAPHS

A number of photographs are included showing some of our work accomplished or under way.

L. W. BRYAN, Associate Forester.



Clearing line for tree planting in uluhi fern area. Waiaha Spring Reserve.



Planting trees in Waiaha Spring Reserve.



Cleaning around young trees, land of Piilhonua, Hilo Reserve.



Working on Pololu horse trail, Kohala Reserve.



Keanakolu-Hopowai truck trail.



Finished section of Popolu horse trail.

Studies of Enzyme Action in Sugar Cane

1. THE CHARACTERISTICS OF ENZYMES AND THEIR IMPORTANCE IN THE GROWTH AND NUTRITION OF PLANTS.

By CONSTANCE E. HARTT

Enzymes aid chemical changes:

How plants and animals carry on within their cells the intricate chemical processes which are essential for life, is a question not yet definitely answered. When a cutting of sugar cane is placed in the soil, a portion of the cane sugar stored in the cutting must be digested to the simple sugar glucose before the eye can sprout. This process of digestion takes place at a moderate temperature, since the temperature of a plant is very nearly that of the surrounding soil or atmosphere; but if a chemist wishes to convert pure cane sugar to glucose, he boils the sugar with some acid. Many other chemical processes occur in plants at normal temperatures which require boiling and the use of special reagents to be reproduced in the test tube. *The active agent which enables a plant to carry on a chemical change at a moderate temperature is called an enzyme.* The enzyme which aids the digestion of cane sugar to glucose and fructose is called invertase.

Enzymes are catalysts:

Before continuing with the subject of enzymes a few explanatory remarks about catalysts will be offered, because enzymes are catalysts. It is well known that water is a compound composed of the two elements, hydrogen and oxygen. At high temperatures hydrogen and oxygen combine in the formation of water. This combination of hydrogen and oxygen in the formation of water occurs also at room temperature, but only immeasurably slowly. If, however, some spongy platinum is added then even at room temperature the production of water occurs. Thus the platinum aids the formation of water from the hydrogen and oxygen and enables that process to occur at room temperature. The platinum is an example of a *catalyst*, a substance which merely by its presence speeds up chemical changes.

In living plants and animals there are many substances which speed up life processes, such as digestion, and these substances are called enzymes. Because enzymes are complex organic compounds, they are called *organic catalysts*.

Enzymes have the ability to increase the speed of chemical reactions which would ordinarily take place only very slowly at moderate temperatures. It is thought that enzymes do not cause chemical processes to start, but merely affect the speed of the reactions.

Saliva contains an enzyme:

Familiar examples of enzymes* include the ptyalin of our saliva, a kind of

* See table of enzymes at end of article, which summarizes all the enzymes mentioned in this paper.

diastase which aids in the digestion of starchy foods. Preparations of diastase are sometimes prescribed by physicians to aid in digestion; in fact one good quality attributed to such drinks as "cocomalt" is their diastase content.

It has long been known that the papaya has qualities favorable to digestion, and it has even been suggested that hanging tough meat on a papaya tree will render it tender. Be that as it may, the papaya plant does contain a protein-digesting enzyme of great strength. This enzyme is called papain. Preparations of papain are obtainable on the market and are sometimes recommended to be taken by people suffering from indigestion.

Enzymes are important in many industries:

The importance of yeast in the brewing industry is well known but it may not be so generally understood that the agent within the yeast plant which is responsible for the fermentation of sugar and production of alcohol is an enzyme which is called zymase. Many other examples of the uses of enzymes in various industries might be mentioned, including textile industries, tanning, the preparation of beverages, the preparation of fruit extracts, making bread, manufacture of cheese, production of syrups and confections, manufacture of soya sauce, poultry feeding, ripening of tobacco, fermentation of cacao, as laboratory reagents, and in medicine.

Enzymes are also employed in the sugar industry. Preparations of invertase are used in the analysis of sugars in the laboratory. Invertase is also used in the manufacture of syrups from sugar cane. In South Africa, the use of diastase was recommended for the removal of starch by mills grinding Uba cane, since the presence of starch in the juices leads to difficulties in the process of clarification.

Enzyme activity may be strong or weak:

Enzymes are known by what they do rather than by what they are. Hence the actual amount of enzyme present in a plant cannot yet be expressed, but instead the term "activity" is used, which represents the ability of an enzyme to cause a change in another compound. If the amount of change is great the enzyme is said to be very active, but when the amount of change is small, the activity of the enzyme is weak.

Enzymes are capable of causing a transformation in a very large amount of material; but it is also true that the amount of material converted is proportional to the amount of enzyme present. Thus if a plant has a very weak invertase activity, the digestion of cane sugar to glucose and fructose will proceed slowly; a plant with weak protein enzymes, such as peptase and ereptase, will manufacture proteins only slowly and thus growth may cease.

Special enzymes are required for different kinds of chemical changes in plants:

Enzymes, secreted by the living protoplasm of a cell, are considered essential for almost every chemical change which occurs in a plant. A particular enzyme is necessary for each type of transformation, that is, one special enzyme (diastase) aids in the digestion of starch; another (oxidase) is essential for the process of respiration, which releases energy stored in food used in growth; another

(reducase) aids in rendering nitrates utilizable by plants; and there are many others. Each enzyme is responsible for one particular process, and if a certain enzyme is weak or absent, the process for which it is essential cannot take place normally, and growth may cease or the chemical composition of a plant may be altered.

Composition of plants depends upon enzymes:

Not only do enzymes affect the speed of chemical changes but they may also determine what kind of chemical process may occur in a given plant. Thus according to the kind of enzyme present in a plant, glucose can be broken down to lactic acid, or to alcohol and carbon dioxide. An interesting illustration of the relation between enzymes and chemical composition is the lack of starch in the onion plant, which is associated with the absence of diastase.

The possibility of changing the composition of a plant by introducing a foreign enzyme or bacterial culture into the growing plant was demonstrated recently by Suit and Hibbert (11), who grew potato plants which produced potatoes lacking starch due to the introduction of cultures of a certain kind of germ (*Bacillus subtilis*), which makes levan (a storage food built up from fructose) instead of starch (a storage food built up from glucose).

Haldane (3) discusses the effect of enzymes upon chemical composition as follows: "Consider a substance A, of which, in the absence of a catalyst, 99 per cent is converted into B, and 1 per cent into C. If a catalyst accelerates the latter process a millionfold, 99.99 per cent will be converted into C, and only 0.1 per cent into B. Hence the fate of A is qualitatively altered. Enzymes do not merely accelerate metabolic processes, they determine their direction." Haldane refers, of course, to the effect of enzymes upon the direction of metabolic processes, not upon the direction of a single reaction. Thus, in the potato described above, the foreign enzyme changed the direction of the metabolic processes connected with the storage of foods from the manufacture of starch to the manufacture of levan; but in a reversible reaction, for example that between maltose and glucose (maltose = glucose) the enzyme maltase accelerates the speed of the reaction in both directions.

Enzymes are very sensitive to temperature, acidity, chemicals and other conditions:

Temperature has a great effect upon enzymes. If the temperature gets too high, an enzyme is quickly destroyed; in fact enzymes are active only at moderate temperatures. The temperature which destroys an enzyme is specific for each enzyme. For example, the diastase of the bean is destroyed at 131°F. to 140°F.; the protein enzymes of certain bacteria are destroyed at 135°F., and for most enzymes the rapidity of inactivation quickly increases above 122°F. Reducase, however, is not destroyed by boiling. The best temperature for most enzymes lies around 98°F.

Acidity has a profound effect upon the activity of enzymes. If the hydrogen ion concentration is not favorable, the activity of the enzyme ceases or is very weak. Each enzyme requires a certain acidity for its best action, and when either more or less acid the enzyme is less active. Thus if one wishes a particular enzyme to be very active, the acidity must be made favorable. Conversely, if one wishes to prevent enzyme action it is only necessary to render the acidity or alkalinity unfavor-

able. An interesting example of the influence of acidity upon enzyme action is found in the human body. The digestion of meat (protein) occurs both in the stomach and in the intestine; in the stomach the digestive juice contains an enzyme which is active only when very acid and the acidity is furnished by the hydrochloric acid contained in the stomach; but in the intestine there is no acid, the conditions being alkaline, and in the intestine the digestion of meat is carried on by enzymes requiring an alkaline medium.

Enzymes are not only sensitive to temperature and acidity but also to specific salt content. Diastase, for example, is not active in the absence of salts, and its activity is particularly favored by the presence of phosphorus. Oxidase requires manganese to aid in its action. Sugar cane plants deficient in potash were found to have weaker invertase and less manufacture of sugar than plants adequately supplied with potash (5, 6). In the tomato the reduction of nitrates (preparation for use) by reducace does not proceed normally in the absence of phosphorus, potassium, or sulphur. The papaya contains a protein enzyme named papain, the activity of which is stimulated by hydrogen cyanide. Many more examples might be mentioned, but enough have been given to illustrate the importance of specific chemicals in affecting the activity of enzymes. Much remains to be done in this type of research as the field is still young. In a recent review of the subject of the mechanism of enzyme actions, Falk (2) states that one of the most important of the recent advances in enzyme studies is the influence of added substances. The same author considers it evident that enzymes in every living organism must be influenced by the apparently inactive materials present. Such influences, according to Falk, include directive actions, the ability to increase or decrease enzyme activities, and the possible action of one enzyme upon another. Falk states that in a living organism an enzyme never acts in the pure state, and he stresses the importance of the influence of external factors upon enzymes. Oparin (8) has given evidence of the importance of adsorption (a kind of loose attachment) and subsequent removal as a possible mechanism regulating the activities of enzymes in living cells.

What plant processes are affected by enzymes?

Before discussing the life processes in plants which are affected by enzymes, a word about similar processes in the human body may be in order. The food which we eat must be digested before it can give us strength or build up muscles, etc. Digestion occurs in the mouth, stomach, and intestines and in each of those organs enzymes are exceedingly important in speeding up the process of digestion. In the process of digestion, complex solid foods like bread, meat, vegetables, etc., are changed into simple substances which can be dissolved. These simple foods pass through the delicate walls of the stomach and intestines into the blood and are carried to every part of the body, where the food is used to build up new tissues and to furnish strength. To set free the latent strength (or energy) and the heat contained in the food, the food must be burned. This may be compared to the burning of wood or coal to furnish heat. This process of the burning or oxidation of the food takes place all over the body. It requires oxygen which is brought by the blood, having been obtained from the lungs in the process of breathing. This re-

lease of strength and body heat from our food occurs at the temperature of the body, and enzymes are essential for the process.

The metabolic processes in plants which are regulated by enzymes include the *digestion* of foods, processes which require water and are therefore called hydrolyses. Seeds, cuttings and other parts of plants used in propagation contain a supply of food usually in concentrated form, including carbohydrates, fats, or proteins. Before these foods can be used in the growth of plants they must be digested and a special enzyme is necessary to carry on the digestion of each food. Digestion by enzymes is also essential for the removal at night of assimilates stored temporarily in the leaf during the day, rendering complex substances simpler and soluble and readily translocatable. After a food is digested, that is, rendered simpler and soluble, then the process of *respiration* can occur. Respiration in higher plants such as sugar cane involves the utilization of oxygen in the oxidation of foods, and results in the release of energy which is used by the plant for growth and for the manufacture of complex compounds. Just as man cannot live without breathing, so a plant cannot live without the respiration of foods, and for this essential life process several enzymes are required, for example oxidase. The *storage of foods* in plants also involves enzyme action, and it is now generally recognized that the action of most enzymes is reversible. Not only can enzymes convert complex compounds into simpler ones, but they can also build up complex substances from their simpler components. The same enzyme is thought to aid in both the manufacture or synthesis and the digestion of a compound, the direction of the reaction at a given moment whether toward manufacture or toward digestion, being regulated by conditions inside the cell. Armstrong and Armstrong (1) in a new monograph on carbohydrates state: "... there is no doubt that in the plant, enzymes function as synthetic agents." Haldane (3), an English authority on enzymes, says: "But where any given reaction is concerned, an enzyme, like any other catalyst, cannot alter the final state of equilibrium, and if it accelerates any reaction, it must accelerate the reverse action to about the same extent." Although the demonstration of the synthetic action in the test tube is exceedingly difficult because of the conditions and lengthy manipulations involved, it has been accomplished with several enzymes, e.g., emulsin, maltase, urease, and pepsin (3). The manufacture or synthesis of cane sugar is attended with especial difficulty, which will be discussed in another report. Oparin and Kurssanow (9) have reported the synthesis of a sugar identical with cane sugar by the simultaneous action of the two enzymes, invertase and phosphatase of yeast. *Other processes* regulated by enzymes include the reduction of nitrates by reducase, the breaking down of hydrogen peroxide by catalase resulting in the formation of water and oxygen, the formation and destruction of the green pigment chlorophyll by chlorophyllase, the fermentation of glucose by zymase, and many others. It is thought that one step in the process of photosynthesis (manufacture of sugar by green plants with the aid of sunlight) is an enzyme reaction.

At every age, in every organ, literally multitudes of chemical changes are taking place in plants, each one regulated by its own enzyme. Each living cell is the seat of many enzymatic processes, and the protoplasm and wall of which the cell is made as well as the food inclusions within the cell are all considered the results of the activities of enzymes. These sensitive agents, readily activated and inactivated by many internal and external factors, are important in many processes absolutely

essential for growth, and regulate many reactions centering around the formation, utilization, and storage of sugar.

Glucose, a simple sugar, undergoes many changes in plants and is greatly affected by enzymes:

It is interesting to speculate upon the fate of a molecule of glucose just formed from carbon dioxide and water by the aid of the green pigment chlorophyll and sunlight in a cell of a sugar cane leaf. It may unite or condense with other similar molecules in the formation of a grain of starch inside the chloroplast and in the evening be released again by the digestion of the starch. It may unite with a nitrogenous compound, go into the formation of a complex molecule of protein, and be used in the formation of protoplasm. It may go through a series of changes not yet fully understood, the ultimate product being fat; as part of a molecule of fat it may form a part of the outer layer of protoplasm and help regulate the permeability of the cell to water and salts. Our molecule of glucose may unite with many of its fellows, lose a lot of water, and result in the formation of cellulose and other cell wall materials. The glucose may go into the formation of pectic substances which may unite with calcium resulting in the calcium pectate layer of the cell wall, which is so important in cementing the cellulose walls of neighboring cells together. Numerous other complex organic compounds, with various functions in the life of the plant, may be formed from glucose. From the standpoint of the sugar industry the most important of these is sucrose, the cane sugar of commerce. The surplus glucose which is not used in the manufacture of complex organic compounds, and which is not used directly for the release of energy in the process of respiration, that surplus glucose according to a theory accepted by many plant physiologists goes into the formation of cane sugar. According to the same theory, the manufacture of cane sugar requires fructose (fruit sugar) as well as glucose (grape sugar), and it is not known whether all the fructose is made from glucose (this process is known to occur, although the mechanism is unknown), or whether some of the fructose arises simultaneously with the glucose in the process of photosynthesis. Plant physiologists today are more and more coming to the conclusion that glucose and perhaps fructose as well, are the primary sugars in photosynthesis. This process of the union of glucose and fructose in the formation of cane sugar, which perhaps takes place both in the leaf and in the stem of sugar cane, will be considered in detail in another paper. All of these metabolic processes are regulated by enzymes.

The fate of glucose in a plant depends upon chance, age, water content, and enzyme activity:

With so many avenues open to our hypothetical molecule of glucose one may well wonder what determines the precise path of any given molecule of glucose. Of course chance plays an important part. If the plant is young and actively growing, much of the glucose will be used in respiration, as young plants require lots of energy just like growing boys. Large amounts of glucose in rapidly growing plants are also required in the building of protoplasm and cell walls of new leaves, etc. The deep-green leaves of young plants are good photosynthetic organs, so that there

is always some surplus glucose to be stored as cane sugar. In an older, more mature plant growth slows down and eventually ceases; in such a plant less glucose is required for current needs and the result is more cane sugar for storage. These comparisons for young and old apply to different parts of the same plant as well as to plants of different ages. Older parts of a plant do not grow but form or store chiefly cane sugar, while young parts grow rapidly and use a considerable amount of glucose.

Another factor determining the course of chemical changes in plants is the amount of water. The importance of curtailing the supply of irrigation water as a means of decreasing growth is well known and has already been discussed elsewhere (7). The formation of starch, cellulose, proteins and other complex organic compounds probably including cane sugar, are known to chemists as condensation processes, and they take place better under conditions of drying out or the withdrawal of water. The digestion of these products requires the utilization of water. Hence the direction of a chemical reaction, whether favoring digestion or manufacture, is largely dependent upon the supply of water in the cell in which the reaction occurs. The cell may have a high moisture percentage, but if water is being withdrawn the conditions for condensation and manufacture are found. The effect of water upon chemical composition was discussed by Spoehr (10) in his study of the carbohydrate economy of cacti; low water content and high temperature were associated with an increase in polysaccharides (complex foods like starch), decrease in monosaccharides (simple sugars like glucose), and increase in pentosans, while a high water content and low temperature were associated with a decrease in polysaccharides, increase in monosaccharides, and decrease in pentosans.

Any factor which decreases growth but does not interfere seriously with photosynthesis is apt to result in increased storage of cane sugar.

One of the most important factors governing the type of chemical reaction, determining the fate of our glucose molecule, is the nature and activity of the enzymes in that particular cell and plant. A plant containing no diastase forms no starch, for example the onion, leek, narcissus. A plant containing generally weak diastase forms starch in comparatively small amounts, for example sugar cane. A plant containing strong invertase forms and stores cane sugar.

Growth and sugar production in the sugar cane plant are processes affected by enzymes:

For a plant to grow normally it must be able to manufacture and digest proteins, since proteins are essential for the formation of protoplasm or life substance. Both the formation and digestion of proteins require protein enzymes, for example peptase and ereptase. Some evidence indicates that sugar cane plants which are weak because of lack of potash, have weak peptase activity and poor formation of proteins (4, 6). The processes of digestion, manufacture of food, formation of protoplasm and cell walls, and respiration—which have already been discussed in this paper—are all essential for growth and are all dependent upon enzymes.

Sugar cane plants deficient in potash had weak invertase activity and poor formation of sugar (6). Other experiments to be reported in a later paper of this series also indicate a relationship between sugar and invertase. One step in

the process of photosynthesis (the manufacture of sugar by green plants with the aid of sunlight) is thought to be an enzyme process.

For many years the increase in the percentage of cane sugar in the sugar cane plant has not been commensurate with the increase in the applications of fertilizers, although the tons of sugar per acre have increased due to the greater tonnage of cane. Economy in handling plant material demands an enrichment of the juices. Because of the great importance of enzymes in regulating growth, formation and utilization of sugar and other chemical processes in plants, and because of the sensitivity of enzymes to fertilizer constituents, acidity, and other conditions, it is felt that studies of the effects of various factors upon the activities of enzymes in the sugar cane plant may lead to a physiological basis for fertilizer applications and other cultural practices as well as to the enrichment of the juices.

Such studies are now under way, and it is our intention to report first upon the functions of invertase and certain factors affecting its activity, and later upon other enzymes in sugar cane.

For convenience, a partial list of enzymes is given, together with the substrates or compounds upon which they act. It is thought by many physiologists that the reverse or synthetic action is catalyzed or aided by the same enzyme although as already stated the synthetic action has been demonstrated in comparatively few instances. The enzymes which we have already studied in sugar cane include invertase, amylase, dextrinase, maltase, peptase, ereptase, catalase, oxidase, peroxidase, and reducase. Others will be studied as time permits.

It is not the purpose of this paper to discuss the details of the studies of the chemical composition of enzymes or the theoretical considerations of the mechanism of enzyme action. Six enzymes have been crystallized and it is said that certain if not all enzymes are proteins (12). The exact chemical composition of enzymes remains to be determined and is a problem for the chemist rather than the physiologist. For a general reference to the subject of enzymes the reader is referred to Waksman and Davison (13).

Partial List of Enzymes in Plants

ENZYME (a)	SUBSTRATE (b)	END PRODUCT (c)
1. Carbohydrate enzymes		
invertase	sucrose	glucose and fructose
maltase	maltose	glucose
diastase	starch	maltose
amylase	starch	dextrine
dextrinase	dextrine	maltose
cellulase	cellulose	cellobiose
cytase	hemicelluloses	dextrines and simple sugars
pectase	pectic substances	simple sugars
inulase	inulin	fructose
2. Protein enzymes		
peptase	complex proteins	peptones and proteoses
ereptase	peptones and proteoses	amino acids
papain	proteins	amino acids

3. Fat enzymes

lipase	fats	fatty acids and glycerine
chlorophyllase	chlorophyll	alcohol+phytol+chlorophyllid
phosphatase	organic phosphorus compounds	fructose+phosphoric acid

4. Respiratory enzymes

oxidase	phenol-like compounds	active oxygen
oxygenase	phenol-like compounds	organic peroxides
peroxidase	organic peroxides	active oxygen
zymase	glucose, fructose, mannose, galactose	alcohol+carbon dioxide+energy

5. Catalase

hydrogen peroxide	water+oxygen
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6. Reducase

nitrites	nitrites
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- (a) The generally accepted nomenclature of enzymes today is the addition of the suffix (-ase) to the name of the compound upon which the enzyme acts or the type of reaction catalyzed by the enzyme. Some of the enzymes first discovered were not named in accordance with this method.
- (b) The substrate is the substance upon which the enzyme acts.
- (c) The end product is the result of the action of the enzyme upon the substrate.

LITERATURE CITED

- (1) Armstrong, E. F., and Armstrong, K. F. 1934. The carbohydrates. Longmans, Green and Co., New York.
- (2) Falk, K. G. 1935. The mechanism of enzyme actions. *Science*, Vol. LXXXI, pp. 471-475.
- (3) Haldane, J. B. S. 1930. *Enzymes*. Longmans, Green and Co., New York.
- (4) Hartt, C. E. 1929. Potassium deficiency in sugar cane. *Bot. Gaz.*, Vol. LXXXVIII, pp. 229-261.
- (5) ————. 1933. Studies of the invertase of sugar cane. A preliminary report. *The Hawaiian Planters' Record*, Vol. XXXVII, pp. 13-14.
- (6) ————. 1934. Some effects of potassium upon the amounts of protein and amino forms of nitrogen, sugars, and enzyme activity of sugar cane. *Plant Physiology*, Vol. IX, pp. 453-490.
- (7) ————. 1934. Water and cane ripening. *The Hawaiian Planters' Record*, Vol. XXXVIII, pp. 193-206.
- (8) Oparin, A. 1934. Die Wirkung der Fermente in der lebenden Zelle. *Ergeb. d. Enzymforsch.* 3, pp. 57-72. (Leipzig.)
- (9) ————, and Kurssanow, A. 1931. Über die enzymatische Synthese des Rohrzuckers. *Biochem. Ztschr.* Vol. CCXXXIX, pp. 1-17.
- (10) Spoehr, H. A. 1919. The carbohydrate economy of cacti. *Carn. Inst. Wash. Pub.* 287, 79 pages.
- (11) Suit, R. F., and Hibbert, H. 1934. A starchless potato induced by the introduction of foreign enzymes. *Science*, Vol. LXXIX, pp. 78-79.
- (12) Sumner, J. B. 1935. *Enzymes*. *Ann. Rev. Biochem.*, Vol. IV, pp. 37-58.
- (13) Waksman, S. A., and Davison, W. C. 1926. *Enzymes*. The Williams and Wilkins Co., Baltimore.

Some Plant Food Values in Molasses and Filter Cake

By RALPH J. BORDEN

It is estimated that as a result of grinding some eight and a half million tons of cane in 1933, there were produced therefrom over 200,000 tons of filter cake mud and more than 235,000 tons of molasses, only about 35,000 tons of which were sold. Both of these by-products have been used for many years by our plantation men, and when applied to cane fields we have heard many and varied opinions regarding their value for increasing profits.

In an article discussing "Filter Mud and Molasses" (1) by H. P. Agee, two statements have challenged us, i.e., (a) "The agricultural value of molasses is so poorly established that when the market for this material is weak, thousands of tons of it are put into the sea;" and (b) "It is possible that unless we take full account of the fertilizing value of filter press mud, and adjust our commercial fertilizers to conform, we may forego the profit we are accustomed to attach to the use of it." Hence we were encouraged to plan a series of controlled "skirmish" tests, using an indicator crop (Sudan grass) in pots which we hoped might enable us to evaluate or determine the relative crop-producing efficiencies of the principal plant foods carried by these two important by-products of the sugar mill, as compared with the crop-producing values in equivalent units of inorganic commercial fertilizer materials. This series of pot studies is at a stage now where we can make a progress report on some of the actual results that have been obtained.

I

We first used an acid soil from Manoa Field 9 that was fairly well supplied with nitrogen but deficient in available phosphate and potash as measured by our Mitscherlich test. (This test indicated 208 pounds of nitrogen, 16 pounds of phosphate, and 316 pounds of potash, per acre foot.) This soil was placed in Mitscherlich pots at Makiki and planted to Sudan grass. No leachate is lost from these pots. Two crops were harvested—the plant crop in 71 days and the ratoon crop in 86 days—hence the soil supported plant growth for a total of 157 days. In all cases the plant foods other than the one being evaluated were supplied in sufficient amounts so that they would not be limiting growth factors. All treatments were in duplicate.

Nitrogen in Molasses (2): For the evaluation of nitrogen in molasses, we prepared the soils by mixing in molasses at the rate of 10 tons per acre, both with and without varying amounts of soluble nitrogen fertilizer. This molasses carried 0.63 per cent nitrogen. The soils were kept warm, moist and well aerated for two weeks before planting the seed.

The results from this soil indicate that where molasses was used to supply nitrogen, the yields of dry matter were consistently lower than where molasses was omitted. There are indications of a "luxury consumption" of available nitrogen as well as indications that the molasses when applied at 10 tons per acre on this soil has either tied up or dissipated some 35 or 40 pounds per acre of otherwise available

nitrogen. It would also appear that the disappearance of this nitrogen took place during the growth of the first crop, since the yields from the ratoon crop, which received no further application of any fertilizer, were very small and showed no significant differences between the various treatments. It seems quite apparent that the nitrogen lost (?) to the first crop was not made available to the crop which followed. (These soils have been set aside, without crop, and will be replanted later in the year in an effort to see if this nitrogen can be recovered for use by another plant crop.)

The following summary (Table I) is offered for those who would care to make their own interpretation of the results:

TABLE I
EVALUATION OF NITROGEN IN MOLASSES

Differential Treatment Identity	Pounds Nitrogen per Acre Supplied		Total	—Dry Weights (Grams)—		
	From Molasses	From Fertilizer		Plant Crop	Ratoon	Total
No N	0	0	0	68.2	11.2	79.4
Mol.	126	0	126	29.9	13.4	43.3
$\frac{1}{8}$ N	0	104	104	112.8	11.6	124.4
Mol. + $\frac{1}{8}$ N	126	104	230	73.7	16.3	90.0
$\frac{2}{8}$ N	0	208	208	149.6	16.2	165.8
Mol. + $\frac{2}{8}$ N	126	208	334	114.8	17.9	132.7
1 N	0	312	312	178.9	16.5	195.4
Mol. + 1 N	126	312	438	146.0	17.1	163.1
$1\frac{1}{8}$ N	0	416	416	194.5	20.4	214.9
Mol. + $1\frac{1}{8}$ N	126	416	542	170.6	19.9	190.5
$1\frac{2}{8}$ N	0	520	520	176.8	19.4	196.2
2 N	0	624	624	139.4	29.8	169.2

Potash in Molasses: For the evaluation of potash in this molasses, we used a plan somewhat similar to that used to evaluate the nitrogen, except that we applied molasses at the rate of only 5 tons per acre, and we made a second application of nitrogen to the ratoon crop, so that nitrogen would not be a limiting growth factor for the ratoon.

The results from this test would indicate that an application of 5 tons of molasses on this soil furnished sufficient available potash to produce a total dry weight that was slightly better than the optimum application of 426 pounds of potash from sulphate of potash. The further addition of various amounts (106, 213, 320, and 426 pounds per acre) of soluble potash salts to the soil that had received this molasses, did not significantly increase the yields therefrom. (Due to the fact that the molasses sample drawn for chemical analysis was perhaps not a representative one, the actual amount of potash furnished by the 5 tons of molasses used, cannot be reliably calculated.) The total dry yield for both crops, without potash fertilizer or molasses, was 163.7 grams; this was increased to 256.2 grams when 426 pounds of potash fertilizer were used, and to 274.0 grams when only 5 tons of molasses were applied. (These soils have been replanted for another crop without further application of molasses.)

Nitrogen in Filter Cake (3): For the evaluation of nitrogen in filter cake, we used an application of 5 tons of dry cake per acre, which was equivalent to 20 tons

of wet filter cake (77 per cent moisture), both with and without supplementary nitrogen fertilizer applications. Planting was delayed for two weeks after mixing the filter cake into the soil. Ample phosphate and potash were supplied for two crops. The ratoon crop was given no additional nitrogen. (After a six months fallow period, another crop will be grown in pots with this soil without further addition of filter cake.)

The results to date, on this Manoa soil, which are summarized in Table II, indicate that the application of filter cake decreased the yield when no supplementary fertilizer nitrogen was furnished, but when it was supplemented with available nitrogen, its own nitrogen content was perhaps made increasingly available, more or less in proportion to the amount of available fertilizer nitrogen provided:

TABLE II
EVALUATION OF NITROGEN IN FILTER CAKE

Differential Treatment Identity	Pounds Nitrogen per Acre			—Dry Weights (Grams)—		
	From Filter Cake	From Fertilizer	Total	Plant Crop	Ratoon	Total
No N	0	0	0	68.2	11.2	79.4
F.C.	162	0	162	49.7	13.5	63.2
$\frac{1}{8}$ N	0	104	104	112.8	11.6	124.4
F.C. + $\frac{1}{8}$ N	162	104	266	123.2	16.6	139.8
$\frac{3}{8}$ N	0	208	208	149.6	16.2	165.8
F.C. + $\frac{3}{8}$ N	162	208	370	164.8	16.0	180.8
1 N	0	312	312	178.9	16.5	195.4
F.C. + 1 N	162	312	474	200.0	21.4	221.4
$1\frac{1}{8}$ N	0	416	416	194.5	20.4	214.9
F.C. + $1\frac{1}{8}$ N	162	416	578	222.3	24.9	247.3
$1\frac{3}{8}$ N	0	520	520	176.8	19.4	196.2
2 N	0	624	624	139.4	29.8	169.2

Phosphoric Acid in Filter Cake: For the evaluation of phosphoric acid in filter cake, our plan was the same as that used for evaluating its nitrogen, except that all pots received heavy applications of nitrogen and potash for the plant crop, and in the ratoon crop were given another application of nitrogen (at the rate of 312 pounds per acre). The results (in Table III) indicate quite clearly a comparable and perhaps a greater efficiency of the phosphate contained in filter cake over a water-soluble commercial phosphate material, when the latter was mixed into the high phosphate-fixing, phosphate-deficient, acid-soil type used in this test. (These pots have been replanted and are now growing a third crop.)

A second test (4) on soil from this Manoa Field 9 is a duplicate of the above plan, except: (a) the filter cake was used at the rate of $2\frac{1}{2}$ tons per acre; and (b) the pots were planted immediately after the filter cake and fertilizers were mixed into the soil, i.e., no "incubation" period was allowed for the partial decomposition of the added filter cake prior to planting. The results from the first crop (given in Table IV) are even more impressive and give to the 295 pounds of phosphate carried by the filter cake applied, a crop-producing value that may be interpolated as equivalent to about 700 pounds of a commercial soluble phosphate fertilizer as used on this high phosphate-fixing soil type.

TABLE III

EVALUATION OF PHOSPHATE IN FILTER CAKE

Pounds Phosphate per Acre

Differential Treatment Identity	From Filter Cake	From Treble Super	Total	Dry Weights (Grams)		
				Plant Crop	Ratoon	Total
No P	0	0	0	22.5	116.9	139.4
F.C.	589	0	589	179.5	95.5	275.0
$\frac{1}{4}$ P	0	106½	106½	31.3	120.8	152.1
F.C. + $\frac{1}{4}$ P	589	106½	695½	163.7	94.3	258.0
$\frac{1}{2}$ P	0	213	213	55.6	84.0	139.6
F.C. + $\frac{1}{2}$ P	589	213	802	139.3	94.1	233.4
$\frac{3}{4}$ P	0	319½	319½	77.5	93.8	171.3
F.C. + $\frac{3}{4}$ P	589	319½	908½	167.3	97.4	264.7
1 P	0	426	426	81.8	83.9	165.7
F.C. + 1 P	589	426	1015	197.3	97.5	294.8
2 P	0	852	852	123.8	94.4	218.2
6 P	0	2556	2556	228.3	89.0	317.3

TABLE IV

EVALUATION OF PHOSPHATE IN FILTER CAKE

Differential Treatment Identity	Pounds Phosphate per Acre		Total	Dry Wt. (Grams) Manoa Field 9
	From Filter Cake	From Fertilizer		
No P	0	0	0	1.4
F.C.	295	0	295	77.9
$\frac{1}{4}$ P	0	106½	106½	10.5
F.C. + $\frac{1}{4}$ P	295	106½	401½	75.1
$\frac{1}{2}$ P	0	213	213	26.7
F.C. + $\frac{1}{2}$ P	295	213	508	72.9
$\frac{3}{4}$ P	0	319½	319½	42.9
F.C. + $\frac{3}{4}$ P	295	319½	614½	65.8
1 P	0	426	426	51.8
F.C. + 1 P	295	426	721	89.1
2 P	0	852	852	85.3
6 P	0	2556	2556	133.1

II

A second study of some of the plant food values in molasses and filter cake has been conducted at the Hilo Variety Station. The plan used was only slightly different from the one used at Makiki. Three crops of Sudan grass have been harvested from these pots: a plant, a re-plant, and a ratoon; thus this soil has been cropped for a total of over seven months since the by-products that were being tested were applied. The fertilizer treatments (except the application of molasses or filter cake) of the first crop were repeated for the second crop. For the third crop, only sufficient additional nitrogen or potash to keep them from being limiting growth factors, were furnished.

Nitrogen in Molasses (5): An application of Hilo molasses (1.6 per cent N) at the rate of 10 tons per acre on this Hilo soil that was rather high in available nitrogen (414 pounds nitrogen per acre-foot) showed little if any definite effect on the yields that were harvested. In the first crop there may be an indication of very

slightly lower yields when the molasses was added; if so, then in the second and third crops the indication is for a slightly higher yield. However, the differences between comparative treatments are all so small that they may quite naturally be due to the chance errors that can easily be associated with a test of this nature. Even in the third crop, harvested after the molasses was applied, there is very little evidence to indicate that the addition of a rather large amount of nitrogen in the molasses used, has had any definite influence upon the available nitrogen supply of this soil. Unlike the Manoa soil from Field 9 however, the yields have not been definitely depressed by the molasses application that was made. The results are summarized (in Table V) as follows:

TABLE V
EVALUATION OF NITROGEN IN MOLASSES

Pounds Nitrogen per Acre				—Dry Weights (Grams)—			Total
Differential Treatment Identity	From Molasses	From Fer-tilizer*	Total	First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	
No N	0	0	0	75.1	7.9	8.0	91.0
Mol.	320	0	320	74.6	11.4	9.3	95.3
$\frac{1}{2}$ N	0	208	208	113.3	44.4	12.9	170.6
Mol. + $\frac{1}{2}$ N	320	208	528	101.6	48.2	14.5	164.3
$\frac{2}{3}$ N	0	416	416	135.7	74.8	13.2	223.7
Mol. + $\frac{2}{3}$ N	320	416	736	121.3	75.4	17.4	214.1
1 N	0	624	624	140.5	83.1	18.9	242.5
Mol. + 1 N	320	624	944	136.3	84.0	20.6	240.9
$1\frac{1}{3}$ N	0	832	832	134.4	88.6	18.5	241.5
Mol. + $1\frac{1}{3}$ N	320	832	1152	143.4	91.1	24.7	259.2
$1\frac{2}{3}$ N	0	1040	1040	132.5	76.3	26.9	235.7
2 N	0	1248	1248	130.5	72.7	40.3	243.5
Growing time (days).....				77	78	64	Total 219 days

* Half in first and half in second crop.

Notes: 1. Fertilization to all pots: First crop at 2556 lbs. P_2O_5 and 852 lbs. K_2O
 Second " " 2556 " " " 852 " "
 Third " " 426 " K_2O only

2. Soil from Hilo Variety Station (makai); high in N as indicated by the Mitscherlich test.
3. Test run in Mitscherlich pots at Hilo.
4. Molasses mixed into soil before planting first crop, at rate of 10 tons per acre (analysis at 1.6 per cent N, 4.7 per cent K_2O).
5. Nitrogen fertilizer differentials (as indicated) applied to first and second crops but not to third crop.

Potash in Molasses (6): When ample nitrogen and phosphate were furnished, the potash value in molasses was quite comparable with its equivalent from a commercial fertilizer salt. This was apparent in the first crop, thus indicating its immediate availability. The molasses that was used carried 4.7 per cent potash. It was applied at the rate of 5 tons per acre before planting. The following table of results (Table VI) offers some rather interesting data for speculation.

TABLE VI
EVALUATION OF POTASH IN MOLASSES

Pounds Potash per Acre				—Dry Weights (Grams)—			
Differential Fertilizer Identity	From Molasses	From Fertilizer*	Total	First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	Total
No K	0	0	0	102.8	62.0	31.9	196.7
Mol.	470	0	470	127.8	58.4	48.4	234.6
$\frac{1}{4}$ K	0	213	213	110.2	71.7	48.6	230.5
Mol. + $\frac{1}{4}$ K	470	213	683	118.4	59.1	51.0	228.5
$\frac{1}{2}$ K	0	426	426	120.6	77.7	55.4	253.7
Mol. + $\frac{1}{2}$ K	470	426	896	119.9	54.9	63.2	238.0
$\frac{3}{4}$ K	0	639	639	121.5	79.2	59.8	260.5
Mol. + $\frac{3}{4}$ K	470	639	1109	121.9	63.1	68.5	253.5
1 K	0	852	852	121.8	81.4	66.4	269.6
Mol. + 1 K	470	852	1322	122.7	64.4	72.6	259.7
$1\frac{1}{2}$ K	0	1278	1278	128.9	68.3	68.2	265.4
2 K	0	1704	1704	125.4	81.1	77.3	283.8
Growing time (days).....				76	78	64	Total 218 days

* Half for first and half for second crop.

Notes: 1. Fertilization to all pots: First crop at 624 lbs. N and 2556 lbs. P_2O_5
 Second " " 624 " " " 2556 " "
 Third " " 312 " N only

2. Soil from Hilo Variety Station (makai); indicated by Mitscherlich test to be low in potash and high in nitrogen.
3. Test run in Mitscherlich pots at Hilo.
4. Molasses mixed in at the rate of 5 tons per acre before first planting.
5. Potash fertilizer differentials (as indicated) applied to first and to second but not to third crop.

Nitrogen in Filter Cake (7): Only the nitrogen content of the filter cake was studied in this test at Hilo. Used at the rate of 15 tons of wet (76.3 per cent moisture) cake per acre, with 0.804 per cent N, the filter cake application added 241 pounds of nitrogen to a soil that naturally contained a relatively large available amount of this nutrient. When applied without further supplementary nitrogen fertilizer or with only a relatively small amount, the yields were decreased, especially in the first crop, although in the following two crops there appeared to be a slight yield increase, so that the total yield showed little difference or effect from the nitrogen supplied in the filter cake. When applied with more liberal amounts of commercial nitrogen, this depressive effect of filter cake upon the Sudan grass yields was not apparent, but it is still doubtful if the nitrogen in this filter cake has been responsible for any yield increase on this soil over a period of some seven months of cropping in Mitscherlich pots. The tabulated results are offered below in Table VII:

TABLE VII

EVALUATION OF NITROGEN IN FILTER CAKE

Pounds Nitrogen per Acre				—Dry Weights (Grams)—			Total
Differential Treatment Identity	From Filter Cake	From Fertilizer*	Total	First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	
No N	0	0	0	56.9	9.2	4.7	70.8
F.C.	241	0	241	38.5	16.4	7.0	61.9
$\frac{1}{3}$ N	0	208	208	104.1	55.2	4.5	163.8
F.C. + $\frac{1}{3}$ N	241	208	449	87.9	62.3	7.2	157.4
$\frac{2}{3}$ N	0	416	416	119.8	86.7	5.5	212.0
F.C. + $\frac{2}{3}$ N	241	416	657	121.4	91.1	7.5	220.0
1 N	0	624	624	126.8	105.1	6.9	238.8
F.C. + 1 N	241	624	865	122.0	103.2	7.4	232.6
$1\frac{1}{3}$ N	0	832	832	129.7	94.8	10.6	235.1
F.C. + $1\frac{1}{3}$ N	241	832	1073	134.6	109.7	10.8	255.1
$1\frac{2}{3}$ N	0	1040	1040	128.8	102.7	10.5	242.0
2 N	0	1248	1248	133.1	103.4	13.9	250.4
Growing time (days).....				68	73	72 Total	213 days

* Half for first and half for second crop.

Notes: 1. Fertilization to all pots: First crop at 2556 lbs. P_2O_5 and 426 lbs. K_2O
 Second " " 2556 " " " 426 " "
 Third " " 426 " K_2O only

2. Soil from Hilo Variety Station (makai); high in N (over 300 lbs. per acre) by Mitscherlich test.
3. Tests run in Mitscherlich pots at Hilo.
4. Filter cake mixed into soil prior to planting first crop at rate of 15 tons (76 per cent moisture) per acre.
5. Nitrogen fertilizer differentials (as indicated) applied to both first and second crops but not to third crop.

III

A third study concerned with the evaluation of the nitrogen and potash of molasses was carried out at Makiki. Two potash-deficient soils were used: one from Manoa Field 22 and the other from Ookala Field 10 (Kaiwika Sugar Company, Ltd.). The Manoa soil was very deficient in nitrogen while the Ookala soil had a medium nitrogen supply. The molasses used had an analysis of 0.312 per cent nitrogen and 4.0 per cent potash. It was thoroughly mixed into the soils and allowed to "incubate" for one month before the Sudan grass was planted.

Nitrogen in Molasses (8): The treatments for comparison in this study were different from those which we have previously described. For the evaluation of nitrogen, molasses at 11 and 22 tons per acre (actually 11.38 and 22.76 tons per acre) was used, both with and without a supplementary application of commercial fertilizer nitrogen, and a check treatment carrying the equivalent nitrogen content of the higher rate of molasses application was provided. Ample phosphate and potash were supplied. Here we note a somewhat different effect upon adding molasses to a soil with a low or with a high available nitrogen supply.

On the Manoa soil when the molasses was applied at the rate of 11 tons per acre with no supplementary nitrogen fertilizer, the resultant dry yield was only 15.6 per cent of the yield produced without molasses; when applied at twice this rate or 22

tons per acre, a still further reduction in yield or only 9.7 per cent of the yield without molasses was obtained. When a supplementary application of molasses at 11 tons per acre was given with 312 pounds of fertilizer nitrogen, the resultant yield was only 72.3 per cent of the yield without the molasses; with a supplementary application of molasses at 22 tons per acre, the yield dropped to 42.8 per cent of that secured without the molasses application.

On the Ookala soil, molasses at 11 tons per acre without added fertilizer nitrogen, produced a yield that was 70 per cent of that obtained without molasses; with molasses at 22 tons per acre, the yield was not significantly different from that without molasses. When used to supplement an application of 312 pounds of fertilizer nitrogen, the molasses applied at 11 tons per acre appears to have increased the yield by 11.4 per cent, but applied at 22 tons per acre the yield was not significantly different from that without molasses.

The results follow in Table VIII:

TABLE VIII
EVALUATION OF NITROGEN IN MOLASSES

Differential Fertilizer Identity	Pounds Nitrogen per Acre			—Dry Weights (Grams)—	
	From Molasses	From Fertilizer	Total	From Manoa Soil Field 22	From Ookala Soil Field 10
No N	0	0	0	15.4 ± .48	37.4 ± 3.37
11 tons Mol.	71	0	71	2.4 ± .01	26.2 ± .46
22 tons Mol.	142	0	142	1.5 ± .11	34.1 ± 1.90
½ N	0	142	142	98.4 ± 2.20	123.1 ± 4.74
1 N	0	312	312	137.4 ± 3.14	143.3 ± 4.45
1 N + 11 tons Mol..	71	312	383	99.4 ± 1.03	163.1 ± 1.82
1 N + 22 tons Mol..	142	312	454	58.8 ± 2.13	139.2 ± 4.74
1½ N	0	454	454	133.4 ± 1.94	159.6 ± 4.52

- Notes: 1. One crop only of Sudan grass grown in Mitscherlich pots at Makiki; all treatments in triplicate. Harvested at age of 82 days.
2. Phosphate and potash at the rate of 2556 lbs. and 426 lbs. per acre respectively, furnished all pots.
3. Molasses mixed into soil four weeks before planting, and soils kept warm, moist, and aerated during this period.
4. The Mitscherlich test gave the following indications of available nitrogen and potash in these two soils:
Manoa Field 22 at the rate of 28 lbs. N and 277 lbs. K₂O
Ookala Field 10 at the rate of 153 lbs. N and 226 lbs. K₂O
5. Molasses was used at two rates of applications: 11 and 22 tons per acre (actually at 11.38 and 22.76 tons per acre).

Potash in Molasses (9): To evaluate the potash in molasses in this study, we used a very small per acre application of molasses—1775 pounds per acre—which furnished 71 pounds of potash. When used both with and without supplementary applications of a potash fertilizer salt, on both the Manoa and the Ookala soils, the potash in molasses was equally as good as its equivalent in the fertilizer, as may be seen from the summary in Table IX:

TABLE IX
EVALUATION OF POTASH IN MOLASSES

Differential Treatment Identity	Pounds Potash per Acre			—Dry Weights (Grams)—	
	From Molasses	From Fertilizer	Total	From Manoa Soil Field 22	From Ookala Soil Field 10
No K	0	0	0	60.7 ± 1.51	63.8 ± 5.22
1/12 K	0	35½	35½	75.9 ± 2.30	90.2 ± 2.44
¼ K	0	71	71	78.4 ± 2.55	95.5 ± 2.05
Mol.	71	0	71	89.0 ± .80	97.1 ± 4.16
⅓ K	0	142	142	95.1 ± 1.26	98.5 ± .57
1 K	0	426	426	98.6 ± 3.84	117.4 ± 1.03
1½ K	0	497	497	99.2 ± 1.96	113.4 ± 4.73
Mol. + 1½ K	71	426	497	100.6 ± 1.77	112.2 ± .81

- Notes: 1. One crop only of Sudan grass was grown in Mitscherlich pots at Makiki; all treatments in triplicate. Crop harvested at the age of 82 days.
2. N and P₂O₅ at 312 and 2556 pounds per acre respectively, furnished all pots.
3. Molasses mixed with soil four weeks before planting, and soils kept warm, moist, and aerated during this period.
4. The Mitscherlich test indicated the following amounts of available nutrients in these soils:
 Manoa Field 22 at the rate of 28 lbs. N and 277 lbs. K₂O
 Ookala Field 10 at the rate of 153 lbs. N and 226 lbs. K₂O
5. The amount of molasses used was equivalent to an application of 1775 pounds per acre.

IV

A fourth study (10) concerned with the nitrogen in filter cake has been harvested once at Makiki. A soil from Manoa Field 22 and one from Makiki Field 11 were used, and filter cake at the rate of 20 tons per acre (wet basis, i.e., 77 per cent moisture) was mixed into these soils with varying amounts of inorganic nitrogen fertilizer and an adequate supply of phosphate and potash. The pots were planted immediately after mixing.

The results, given in Table X, show a similar trend toward depressed yields from filter cake unless rather large amounts of soluble nitrogen fertilizer accompany its admixture with the soil. (The pots in this test have been replanted.)

TABLE X
EVALUATION OF NITROGEN IN FILTER CAKE

Differential Treatment Identity	Pounds Nitrogen per Acre			Dry Weights (Grams)	
	From Filter Cake	From Fertilizer	Total	Manoa Field 22	Makiki Field 11
No N	0	0	0	17.7	37.4
F.C.	162	0	162	5.4	11.1
⅓ N	0	104	104	72.0	106.6
F.C. + ⅓ N	162	104	266	42.7	71.1
⅔ N	0	208	208	102.4	159.5
F.C. + ⅔ N	162	208	370	114.6	117.7
1 N	0	312	312	137.9	203.2
F.C. + 1 N	162	312	474	166.8	168.0
1½ N	0	416	416	155.2	182.0
F.C. + 1½ N	162	416	578	187.1	200.0
1¾ N	0	520	520	166.3	221.1
2 N	0	624	624	175.6	226.6

More studies of a similar nature to those discussed herein are being carried on, for it is believed that they can offer us many data concerned with the use of molasses and filter cake as fertilizer material, if they can be correctly interpreted.

GENERAL SUMMARY

In this preliminary or progress report dealing with efforts to ascertain the relative value of the plant food content of molasses and filter cake, as compared with their equivalents in commercial fertilizer salts, we have not attempted to arrive at any final conclusions. The tests were conducted merely as skirmish tests, or "feelers," to see if we could obtain yield differences that would warrant further and more careful study. The difficulties connected with accuracy and reliability in such tests as we have conducted are evident to those who have attempted a similar study. Hence the probable error is apt to be rather high, and the yield differences we have obtained must not be interpreted too definitely as the effect of the differential treatment that was given to the pots with the indicator crop used, or as quantitative differences which would be secured in the field with sugar cane.

There are several things that are worth noting however, in this general summary. Chief among these is the fact that the effect produced upon yields when either molasses or filter cake was applied to the soil, varied with different soils, and perhaps the dominating factor which controlled this effect was the available nitrogen content of the soil that received the application. Hence it would appear problematical that we could quantitatively determine a general relative value or percentage efficiency for the nitrogen content of these by-products, for such a figure will undoubtedly be different, dependent on the available nitrogen content of the soil which is used in any specific study.

The results that we have obtained to date, indicate that we may well raise a question about the general advisability of using these carbonaceous by-products on soils that are low in available nitrogen, or on fields where our nitrogen fertilizer application is not made quite liberally. In fact, the question may be raised whenever we use these materials, as to what proportion of the total purchased nitrogen fertilizer cost should be assessed them. We are not as yet certain that the nitrogen withdrawn from the available supply for the decomposition of these materials (either natural or added) will be returned. We are rather inclined to believe that most of it will never be available for further crop growth on these soils, and since we are sure that it was not leached out, we are inclined to ask if it has been lost as elemental nitrogen during the decomposition processes that have taken place.

Both the potash content of molasses and the phosphate content of filter cake appear to be equivalent to the corresponding nutrients in commercial fertilizers. In fact the phosphate of filter cake appears to be considerably more effective than a water-soluble phosphate fertilizer, when used on an acid soil. However, if these materials are to be used for their potash or phosphate content, with the idea of saving money on purchased mineral fertilizer materials, it must be recognized that some of the purchased nitrogen fertilizers will be used by them, and that such nitrogen may probably be permanently lost to the crop. Hence, what at first might appear to be a direct saving in potash or phosphate fertilizer costs, may not actually prove to be as great, when a proper assessment is made against these by-products

for the available nitrogen that is withdrawn by the soil microbiological activity that is stimulated when the molasses or filter cake is applied.

REFERENCES

- (1) Agee, H. P., and Webster, J. N. P. 1932. Filter Mud and Molasses. The Hawaiian Planters' Record, Vol. XXXVI, pp. 61-72.
 - (2) Agricultural Department Project A-105—No. 45.
 - (3) Agricultural Department Project A-105—No. 46.
 - (4) Agricultural Department Project A-105—No. 46-1.
 - (5) Agricultural Department Project A-105—No. H 16.
 - (6) Agricultural Department Project A-105—No. H 17.
 - (7) Agricultural Department Project A-105—No. H 15.
 - (8) Agricultural Department Project A-105—No. 45A.
 - (9) Agricultural Department Project A-105—No. 45B.
 - (10) Agricultural Department Project A-105—No. 46-2.
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Two Interesting Pests of Sugar Cane in Guatemala

PODISCHNUS AGENOR BURMEISTER AND
SCAPTOCORIS TALPA CHAMPION

By F. A. BIANCHI

Incidental to the work recently concluded in Escuintla, Guatemala, in connection with the introduction of parasites for *Anomala orientalis*, an opportunity was offered to make observations on the sugar cane pests of that country. Although the moth borer *Diatraea saccharalis* is widespread, no cane pest comparable in the extent of its ravages to our cane leafhopper or to *Anomala* is known to cane planters there; but the two insects which form the subject of this paper are of great interest and are certainly of potential importance. Both of these pests were previously known from the area where they were observed by the writer, and one of them had already been doubtfully recorded there as an enemy of sugar cane, but the habits of the other one, *P. agenor*, as far as the writer is aware, were heretofore unknown to any but the growers directly affected.

The full-grown grub and adult stages of *P. agenor* are shown in the accompanying illustrations. It is the more widely distributed of the only two species comprising the exclusively Central American genus *Podischnus*, of the Dynastidae; its range overlapping that of its congener, *P. tersander*, and extending from British Honduras to the Upper Amazon. The long horn-like extension of the head and the peculiar corrugation of the thorax are common to the males of both species, as in other species of the Dynastidae, but they are sufficiently different in detail, although widely variable, to differentiate *P. agenor* from *P. tersander*. The two species also differ in general shape; *agenor* being generally an elongate, oblong insect, while *tersander* is shorter and somewhat dilated posteriorly. In size, the specimens of *P. agenor* collected range from 30 to 36 mm. in length over all, 12 to 14 mm. in width of the thorax, and 16 to 18 mm. in the width of the abdomen, for both males and females.

The habits of the larva are not unlike those of other scarab grubs. In Guatemala it is not known to be of economic importance and showed a decided preference for uncultivated areas, also having been found twice in large numbers in the vicinity of rotten stumps deeply buried in the soil. As might be expected, it appears to practice some degree of upward and downward migration in the soil, for despite its large size it is difficult to find near the surface at any time of the year, except during the beginning of the dry season, in October or November. The larval stage probably lasts not less than two years. One grub collected in the field on November 24, 1932, was then already in the last instar and did not pupate until May 14, 1934, having previously remained about two weeks in a quiescent pre-pupal condition. In the laboratory the larvae ate potatoes quite readily, but did not seem similarly fond of cane rhizomes. They were evidently extremely hardy, in keeping with their rugged appearance. One, having pushed open the bill box in which it was confined, seemed none the worse after crawling about the cement floor of the laboratory for six days without food.



Upper left: Female of *Podischnus agenor* Burmeister. Upper right: Male of same. Below: Full grown larva of same. (All enlarged.)



Left. Unusually severe damage done to cane by *Podischnus agenor*. Right. More usual exterior appearance of the work of the same beetle.

Of the habits of the beetles much remains to be learned. Whether they occasionally or customarily harm other plants, as is very probably the case, was not ascertained. Their feeding habits, however, have been observed to be of great economic importance to cane growers, and the type of damage which they do to the cane crop is shown in the accompanying illustrations, from photographs taken by Dr. F. X. Williams. This damage is due to the boring of both male and female beetles into the cane stalk for the purpose of feeding, and as seen from the outside, is an unsightly hole about an inch in diameter, often with a loose plug or several strands of fibre hanging out, and always with the rind torn and shredded for some distance up and down from the hole, as if the beetle had to tear the rind before being able to bore its way into the underlying tissues. As observed, the beetles entered, in four out of five cases, near one of the root bands in the upper half of the stalk, and in all but a few cases bored upward rather than downward. When the beetle is finished with the damaged internodes, nothing remains but the empty cylinder of the hard rind and a certain amount of loose, dry fiber, partly bunched at or near the entrance hole or dangling from the walls of the tunnel. Thus, although not more than two internodes are usually destroyed, the damage is probably sufficient to render useless the distal portion of the stalk and to prevent its further growth. More than one beetle per hole and more than one hole per stalk were unusual occurrences; but one of the illustrations shows the longitudinal half of a stalk destroyed so completely as to lead one to believe that more than one beetle must have worked on it.

These beetles were apparently of at least partially nocturnal habits. They were never seen in flight during the day, but were found exclusively within their burrows in the cane, where they seemed to be resting rather than feeding. Whether they came out at night and each beetle crawled back into the same hole in the morning, or whether they came out only once to mate and to bury themselves in the soil to deposit their eggs, as appeared more probable, is a question; but the fact that practically all the females picked out of the cane carried a large complement of eggs was in support of the latter supposition.

Adult beetles may live several months in captivity. Of those that were fed pieces of cane, one female caught on May 12 lived until July 21; a second one caught on the same date died on October 10; and a third caught on June 14 lived until November 7. One emerged in the laboratory and not fed at all, lived only 15 days.

As the last appearance of the beetles in large numbers had occurred at "El Salto", the plantation where these observations were made, some six or seven years before the one observed by the writer, it would seem that the pest is usually well controlled by natural enemies. A large black *Campsomeris*, as yet unidentified, is found in this region, and it may be important among these natural enemies, for in the laboratory it would readily paralyze the grub, although never known to parasitize it.

If an infested stalk is smartly tapped near a boring, the beetle crawls hastily out, and this reaction was taken advantage of by the plantation to further reduce the pest. Boys paid according to the number of beetles collected in this manner gathered in the neighborhood of 30,000 in two weeks, during the infestation that the writer witnessed in June of 1934.

The second insect herewith illustrated is *Scaptocoris talpa* Champion, family Cydnidae, of the Heteroptera. It was described by G. C. Champion in 1900 from

specimens collected in Capetillo, Guatemala, and is closely allied to, but easily differentiated from, the other species of its genus, which, although near to the Asiatic *Stibaropus* of similar fossorial habits, is limited to Central America and was founded on the Brazilian *Scaptocoris castaneus* Perty. What its range may be is not known. As both Capetillo, from where the species was described, and Escuintla, where the writer had opportunity of observing it, lie in the same region on the West Coast of Guatemala, the range may be rather limited. We have no record of the existence of *Scaptocoris talpa* elsewhere.

Champion ("A species of *Scaptocoris*, Perty, found at the roots of Sugar-Cane", *Entomologists Monthly Magazine*, Series 2, Vol. XI, p. 255, 1900) implied some doubt that the specimen sent him for description, labelled as having been found at the roots of sugar cane and other grasses, should actually have been feeding on the roots of the cane; but the writer's observations left no room for doubt on that point and showed that the insect so feeding weakened and stunted the cane beyond recovery.

Although found on two or three different occasions and in more than one locality in the vicinity of the town of Escuintla, this insect was generally scarce and abounded only in two small areas. Both of these areas, only one of which was visited, were planted to cane and on the same estate, "Mauricio", about a league from the town. Here the limits of the area of abundance of the pest were very sharp and comprised an extension of only about one acre, where the cane, fourth ratoon, several months old, although of healthy color and appearance, presented a very striking contrast to the immediately adjacent fields in the matter of size and number of canes per stool. The bugs, in all stages of development except the egg stage, could be found in numbers ranging from a dozen to more than 200 per stool, and were very often seen with their proboscises actually stuck into the rootlets of the cane. The stools themselves, however, were full size and showed no symptoms of disease or rot, apart from the fact that only a few of the buds had germinated; showing either that the stools had attained full size during former ratoons before being attacked by *Scaptocoris*, or had done so in spite of its presence, which must, therefore, have reached maximum abundance about the time the writer visited the area, when retardation of cane growth first became obvious.

The above observations were made on the occasion of a first visit to the infested area, on January 31, 1934. During August of the same year a second visit revealed the bug population practically unchanged or undiminished; but at the time of a third visit, October of the same year, after the field had lain fallow for two months, *Scaptocoris* were generally scarcer, practically all in the adult stage and many copulating; and a predator which was at first rather scarce had increased in numbers and seemed likely to control the pest eventually.

This predator, which because of its long life cycle could not be reared to maturity within the time available, is the larva of an Elaterid beetle, a species of the Elaterini, adults of which are very abundant in the region of Escuintla and are about the right size to fit the larva in question. When kept in the laboratory these larvae underwent long periods of starvation without showing noticeable effects; moulted once or twice during the year they were kept under observation and only casually fed; and gave distinct evidence of preferring *Scaptocoris* in all stages of develop-



Upper left: Adult *Scaptocoris talpa* Champion. Upper center and right: Young and old nymphs of the same. Lower figures: Various stages of the Elaterid larva which preys on *Scaptocoris*. (All enlarged.)

ment to other food, including White Grubs, which they were never noticed to devour as they did *Scaptocoris*.

Most details of the life history of *Scaptocoris* are unknown. In both sexes the adults are provided with wings and probably at times undertake to fly, but flight was never observed and adults were seen only in the soil. In the sugar cane area that was badly infested with *Scaptocoris*, the majority of the population was in the upper foot of soil, but the insect could be found, in all stages of development, scattered down to a depth of 20 inches below the surface. On *Panicum maximum* only three or four specimens were ever found together, always in the upper six or eight inches of soil. Copulation was observed several times in the soil, but only one egg was obtained, and that in the laboratory, from a field-collected female. This egg was smooth, translucently white, longer than thick, equally rounded at both ends, and measured 2 mm. in length by just over 1 mm. in thickness. It did not hatch.

In common with a large number of Heteroptera, *Scaptocoris* are provided with odoriferous glands which are capable of producing a very repugnant odor. In a thickly infested area on a hot day, slight disturbance of the soil would cause the smell to permeate the air to quite a noticeable degree.

The sexes are indistinguishable by external characters and measure in the adult stage from 9 to 11 mm. in length and from $4\frac{3}{4}$ to 6 mm. in breadth. The adults may live several weeks in the laboratory if kept in jars of soil with sections of cane. They prefer to puncture the roots which this cane may put forth, but sometimes they also puncture through the rind into the softer zone of adventitious roots, or feed directly on the cut surface of the cane. Of a few individuals collected on August 23, at least one was alive on November 1, 1934.

Sources of Nitrogen

ANHYDROUS AMMONIA *vs.* AMMONIUM SULPHATE *vs.* AMMONIUM NITRATE

By R. J. BORDEN

In view of the interest that has recently been shown in the possibility of using anhydrous ammonia, dissolved and applied in the irrigation water, as a source of nitrogen, we have conducted several tests during the past year with Sudan grass grown in Mitscherlich pots, comparing equivalent amounts of nitrogen from anhydrous ammonia applied as ammonium hydroxide (NH_4OH), ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$, and ammonium nitrate (NH_4NO_3). All pots were given ample and equal amounts of phosphoric acid and potash. All leachates were returned to their respective pots.

The results indicate quite clearly that the relative efficiencies, as indicated by harvested dry weights, of these three carriers of nitrogen were influenced by the soil upon which they were used.

On the acid Manoa soil (pH 5.6) ammonium nitrate was definitely superior to ammonium sulphate, but there was only low significance to the differences between (a) ammonium nitrate and anhydrous ammonia, and (b) anhydrous ammonia and ammonium sulphate.

When used on the only-slightly-acid Waialua Ranch 11 soil (pH 6.5) there were no significant yield differences between any of the three forms of nitrogen used.

On the neutral Makiki Field 11 soil (pH 7.1) there was a favorable significance to the yield differences favoring ammonium sulphate over both anhydrous ammonia and ammonium nitrate, but no difference between these two latter forms.

The slightly alkaline Waialua, Kawaiola 4 soil (pH 7.5) showed a definite preference for ammonium sulphate over anhydrous ammonia, and a favorable preference for the ammonium nitrate over the anhydrous ammonia. The yield difference between the sulphate and the nitrate was of low significance.

The tabulated results follow:

FORMS OF NITROGEN WITH SUDAN GRASS

Field	Original pH	Average dry yields: grams; (4 pots)		
		Ammonium Sulphate (A.S.)	Ammonium Nitrate (A.N.)	Anhydrous Ammonia (A.A.)
Manoa 9	5.6	85.7 $\pm$ 1.7	101.7 $\pm$ 2.3	93.6 $\pm$ 3.1
Waialua Ranch 11.....	6.5	167.4 $\pm$ 4.4	170.2 $\pm$ 1.4	164.8 $\pm$ 3.4
Makiki 11	7.1	152.5 $\pm$ 4.3	138.8 $\pm$ 0.6	136.9 $\pm$ 2.5
Waialua, Kawaiola 4....	7.5	162.4 $\pm$ 3.4	156.2 $\pm$ 2.4	137.8 $\pm$ 4.9

INTERPRETATION OF SIGNIFICANCE OF DIFFERENCES

Field	Favoring	Difference	Significance of Difference
Manoa 9	A.N. over A.S.	16.0 ± 2.9	High
"	A.N. over A.A.	8.1 ± 3.9	Low
"	A.A. over A.S.	7.9 ± 3.5	Low
Waialua Ranch 11.....	A.N. over A.A.	5.4 ± 3.7	Low
"	A.N. over A.S.	2.8 ± 4.6	No
"	A.S. over A.A.	2.6 ± 5.6	No
Makiki 11	A.S. over A.A.	15.6 ± 5.0	Favorable
"	A.S. over A.N.	13.7 ± 4.4	Favorable
"	A.N. over A.A.	1.9 ± 2.6	No
Waialua, Kawaihoa 4.....	A.S. over A.A.	25.6 ± 6.0	High
"	A.N. over A.A.	18.4 ± 5.5	Favorable
"	A.S. over A.N.	6.2 ± 4.2	Low

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1935, TO MAY 23, 1935.

Date	Per Pound	Per Ton	Remarks
March 16, 1935.....	3.05¢	\$61.00	Puerto Ricos.
“ 18.....	3.05	61.00	Philippines, Puerto Ricos.
“ 28.....	3.10	62.00	Philippines, Puerto Ricos.
“ 29.....	3.1267	62.53	Philippines, 3.10, 3.13; Cubas, 3.15.
“ 30.....	3.15	63.00	Puerto Ricos.
April 2.....	3.18	63.60	Puerto Ricos.
“ 3.....	3.20	64.00	Puerto Ricos.
“ 11.....	3.15	63.00	Puerto Ricos.
“ 12.....	3.165	63.30	Puerto Ricos, 3.15, 3.18; St. Croix, 3.15.
“ 16.....	3.225	64.50	Puerto Ricos, 3.20, 3.25; Cubas, 3.25.
“ 24.....	3.33	66.60	Philippines.
May 2.....	3.25	65.00	Puerto Ricos.
“ 23.....	3.35	67.00	Puerto Ricos.
